Beauty Hadroproduction at Fixed Target in Experiment WA92

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- Status of the experimental measurements
- Experiment WA92
- Beauty Sample Selection
- Total Cross-Section
- Single-Differential Cross-Sections
- Beauty Particle Correlations

Fixed Target Experiments

- Low c.m. energy ($\sqrt{s}$ ~ 25 - 30 GeV):
  - σ_{bb} only few nanobarns per nucleon
  - $\sigma_{bb} / \sigma_{int} \sim 10^{-7}$

- Some important steps in *beauty* measurements:
  - WA75 (1985): 350 GeV/c π^- beam on nuclear emulsion
    first *beauty* event observation
  - WA78 (1987): 320 GeV/c π^- beam on Uranium
    first σ_{bb} measurement: σ_{bb} = 3.2 ± 0.4 ± 1.0 nb/N
  - E653 (1993): 600 GeV/c π^- beam on emulsion
    production characteristics and total cross-section for 9 *beauty* hadron pairs

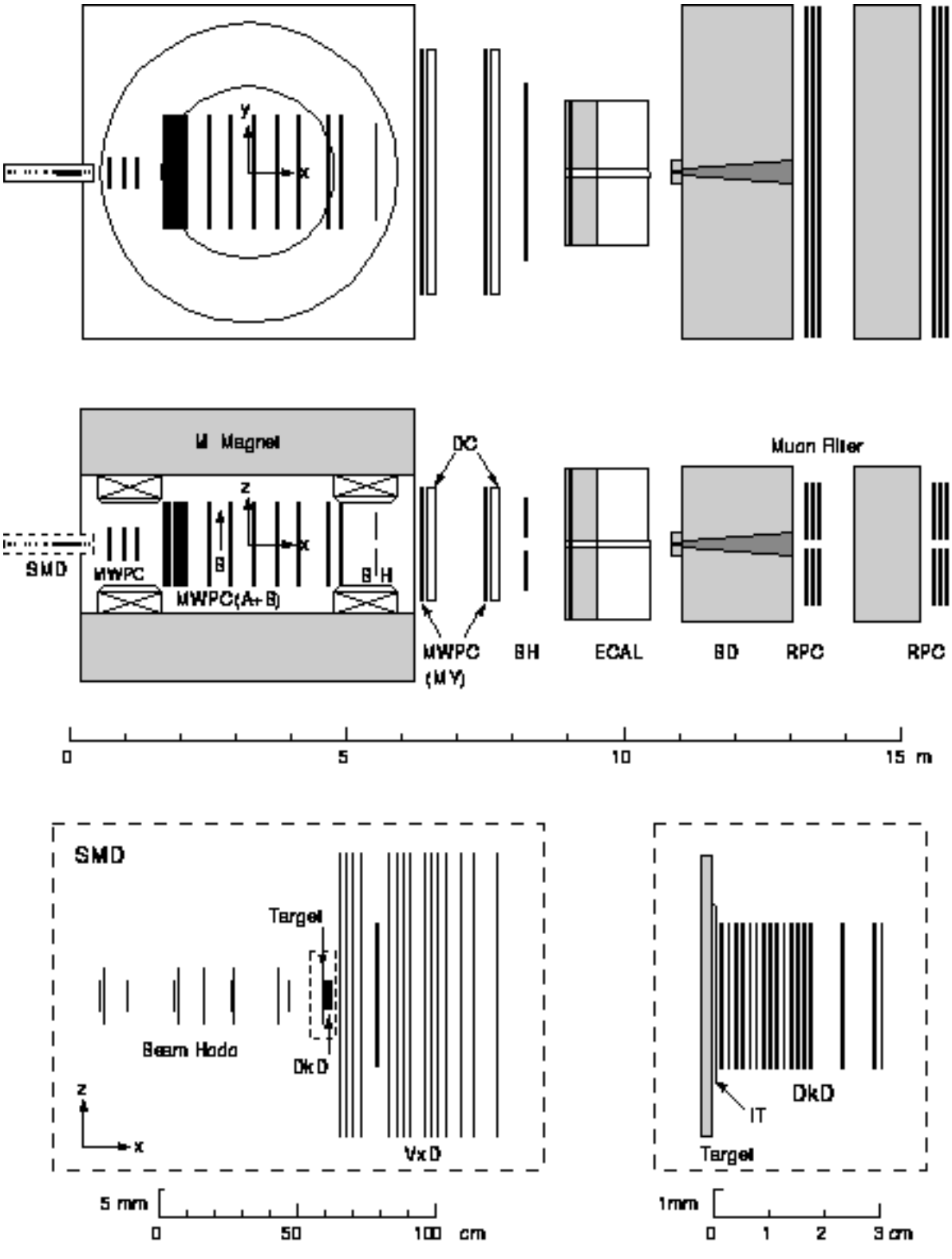
WA92 Characteristics

- *beauty* hadroproduction at $\sqrt{s}$ = 26 GeV
- 350 GeV/c π^- on Copper or Tungsten target
- Total Luminosity:
  - **8.1 nb^{-1} on Cu**
  - **1.5 nb^{-1} on W**
- We use a high-resolution tracking detector and a trigger that exploited the main characteristics of the *beauty* decays.
- We exploit the visualization of the event given by the Decay Detector (DkD):
  - **17 Si microstrips**
  - **10 μm pitch**
  - **coverage of the first 3.2 cm downstream the target**
  - **planes have analogue read-out to reject secondary interactions**

- The Trigger system exploits typical peculiarities of *beauty* decays:
  - **B meson lifetime and Lorentz boost => trigger on secondary vertices**
  - **large fraction of muons in the final state => RPC muon trigger**
  - **B decay tracks with high p_T => hodoscopes p_T trigger**

- Trigger acceptance is ~ 2% for *minimum bias* interactions, 30% for *beauty* and 10% for *charm*
- The present analysis refers on Cu data (~ 3/4 of the total statistics); on tape we get
  - **~ 10^8 events**
  - **150 *beauty* events/nb**
  - **5 10^5 *charm* events**

WA92 layout

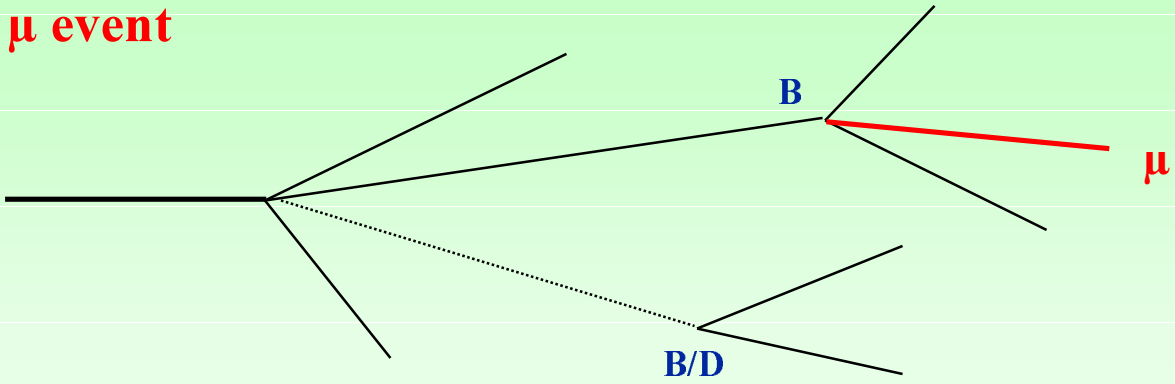

M Magnet
SMD
MWPC
MWPC(A+B)
DC
Muon Filter
MWPC (MY)
BH
ECAL
SD
RPC
RPC
0
5
10
15 m
SMD
Target
Beam Hodo
DkD
VxD
5 mm
0
50
100 cm
DkD
IT
Target
1mm
0
1
2
3 cm

Beauty Selection

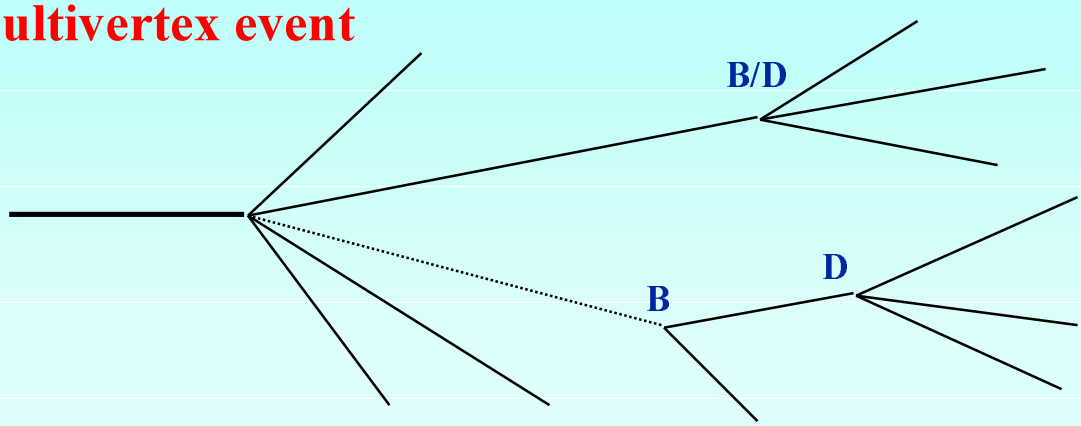
- We select events with secondary activities, rejecting *secondary hadronic interactions* with high energy release on Decay Detector planes
- One of the most powerful criteria of selection is the Neural Network algorithm: a probability to be *beauty* is evaluated for each event. A proper cut reduces events to 30%, keeping 90% of the simulated *beauty* sample
- Events are divided in three samples following their topology:
  - ***non-pointing charm*: 1 fully reconstructed *charm* meson non pointing to the main vertex**
  - ***multivertex*: at least 3 reconstructed vertices in the visibility zone**
  - ***muon*: at least 1 high p_T muon and 1 vertex in the visibility zone**
- These criteria lead to ~ 6000 events to be scanned

Topological samples

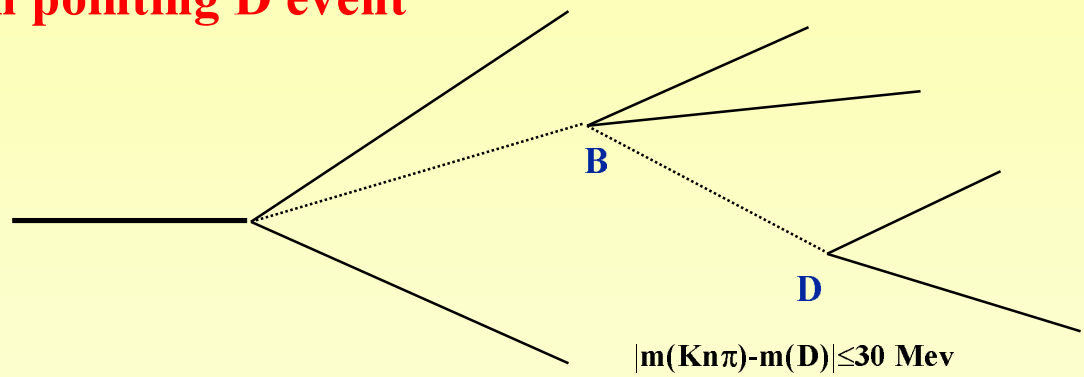
μ event



multivertex event



non pointing D event

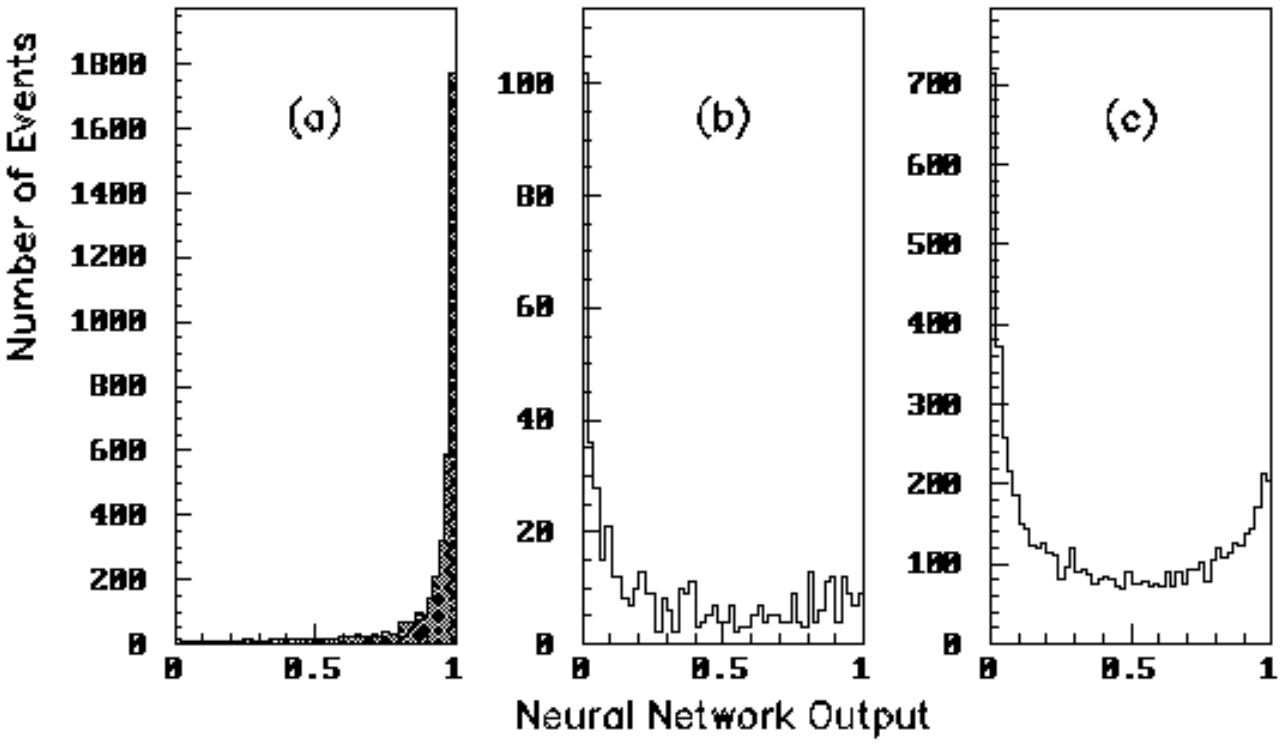


Neural Network Probability

a) Simulated *beauty* events

b) Simulated *charm* events

c) Real data



Scanning Procedure

- A general check on vertices and tracks quality is performed and events with reconstruction problems are rejected.

- Some simple cuts are applied:
  - **no large energy release close to secondary vertices must be confirmed**
  - **no primary tracks linked to secondary vertices**
  - **tracks must have the majority of their hits correctly associated and must be linked correctly to their vertex in both projections**

- Possible vertex chaining in *non-pointing D* and *multivertex* events is verified .

- High-p_{Tf} track from a *beauty* candidate decay is required in *muon* and *multivertex* events.

Beauty Sample

- Finally a sample of 26 *beauty* events is retained:
  - **5 *non-pointing charm* events**
  - **12 *multivertex* events**
  - **12 μ events**
- One event is common to the three scanning classes and one event is common to the *multivertex* and μ classes
- The overall *beauty* acceptance is quite low (-1%) as the cuts are rather stringent but this is necessary to minimize the background

Background sources

- We identify three possible sources of background: *charm* events, nuclear interactions without nuclear breakup, events with in-flight decay of pions or kaons into muons
- *Charm* events (all three classes):
  - **_charm_ cross-section is 3 orders of magnitude larger than _beauty_ cross-section**
  - **we simulated twice the _charm_ present in our data**
  - **0.6 events survive the selection procedure**
- Fake muons (*muon*):
  - **the triggering muon is produced by pion or kaon decays**
  - **a _fake_-μ sample is generated starting from real data: we discard the real muon and force a hadron to decay into a muon**
  - **the background from non-prompt muons is zero**
- White interactions (*non-pointing D* and *multivertex*):
  - **white interactions are secondary nuclear interactions without nuclear breakup and so without large energy release**
  - **they cannot be rejected using the analogue information from the DkD**
  - **real data with black interactions were _whitened_ by erasing the big clusters of energy release in the DkD => 0 events**

Total Cross-Section

- We measure a total cross-section using all 26 *beauty* candidates, assuming a linear A-dependance, integrating over all x_F:

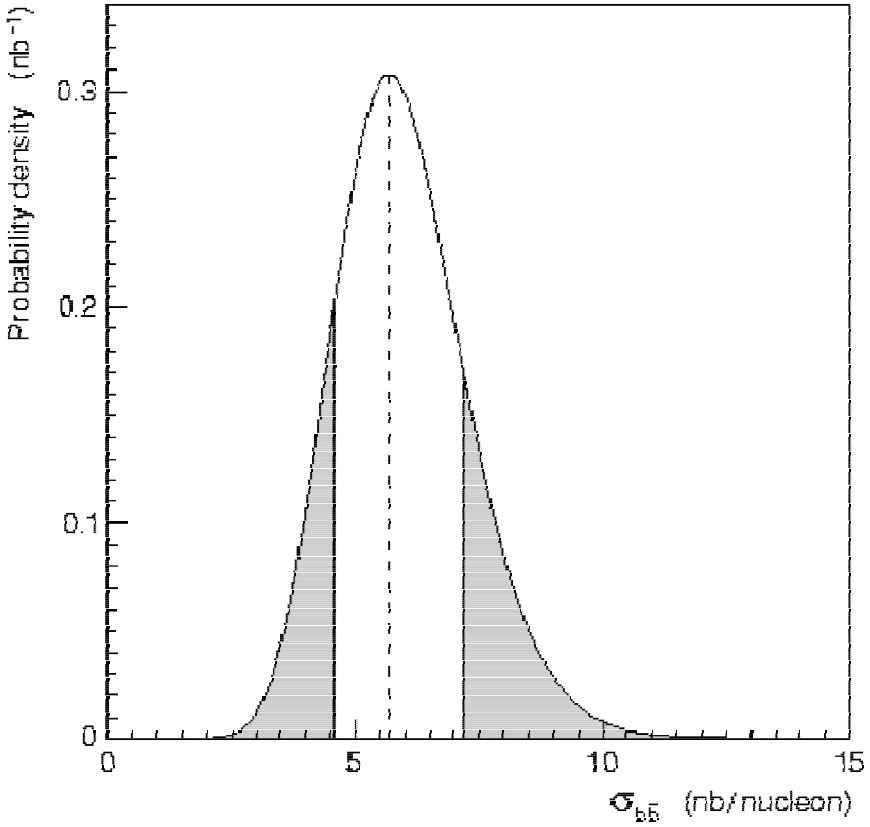
$$\sigma_{bb} = 5.7\ ^{+1.3}_{-1.1}\ \text{(stat)}\ ^{+0.6}_{-0.5}\ \text{(syst) nb/N}$$

- Statistical errors include the fluctuations on N and B; systematic errors include the fluctuations of L and ε
- Compatible results have been found measuring independently the *beauty* production cross-section for each of the three samples.

Total Cross-Section

- The probability-density function (pdf) of the cross-section $P(\sigma)$ is obtained from the convolution of the pdfs P(N), P(B), P(L) and $P(\varepsilon)$
  - **N, B, L, ε are the "true" values of N, B, L, ε**
  - **P(L), $P(\varepsilon)$ are assumed to be gaussian truncated at ±3 standard deviations**
  - **P(N), P(B) are inferred from N and B assuming a Poisson distribution for N and B**
- The nuclear cross-section is given by:

$$\sigma_0 A^{\alpha} = (N-B) / L\varepsilon$$


Probability density (nb^{-1})
0.3
0.2
0.1
0
0
5
10
15
$\sigma_{b\bar{b}}$ (nb/nucleon)

Total Cross-Sections

- As a check we have measured independently the *beauty* production cross-section for each of the three samples following the same procedure. We get:

  - for the *muon* class:

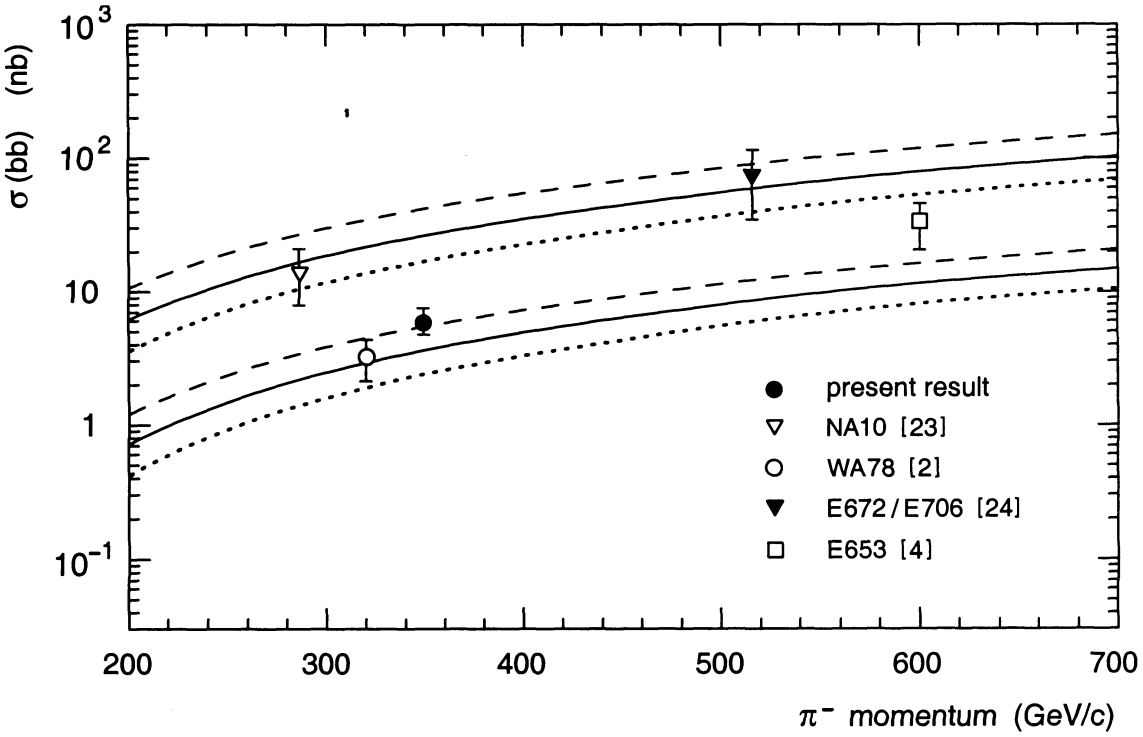
$$\sigma_{\mu} = 6.2^{+2.4}_{-1.7}\ (\text{stat})\ ^{+0.9}_{-0.6}\ (\text{syst})\ \text{nb/N}$$

  - for the *multivertex* class:

$$\sigma_{\text{mvtx}} = 5.2^{+2.0}_{-1.3}\ (\text{stat})\ ^{+0.8}_{-0.6}\ (\text{syst})\ \text{nb/N}$$

  - for the *non-pointing charm* class:

$$\sigma_{\text{npD}} = 6.0^{+4.0}_{-2.5}\ (\text{stat})\ ^{+1.6}_{-0.8}\ (\text{syst})\ \text{nb/N}$$

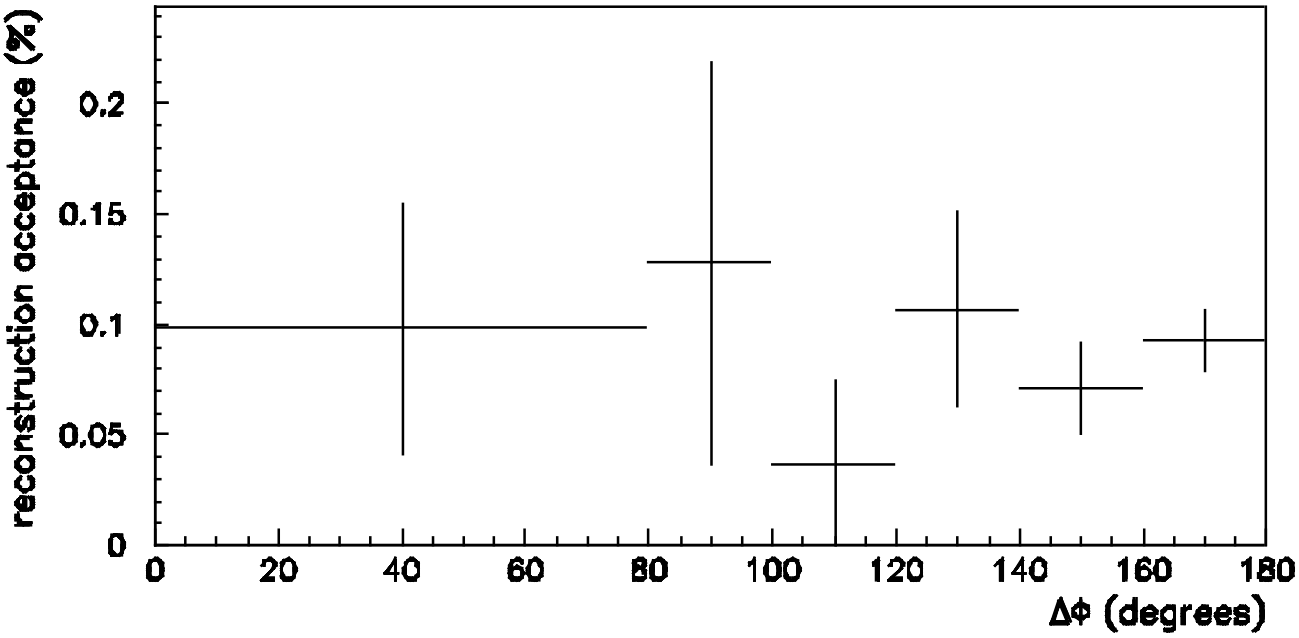

σ (bb) (nb)
10^3
10^2
10
1
10^-1
200
300
400
500
600
700
π⁻ momentum (GeV/c)
present result
NA10 [23]
WA78 [2]
E672 / E706 [24]
E653 [4]

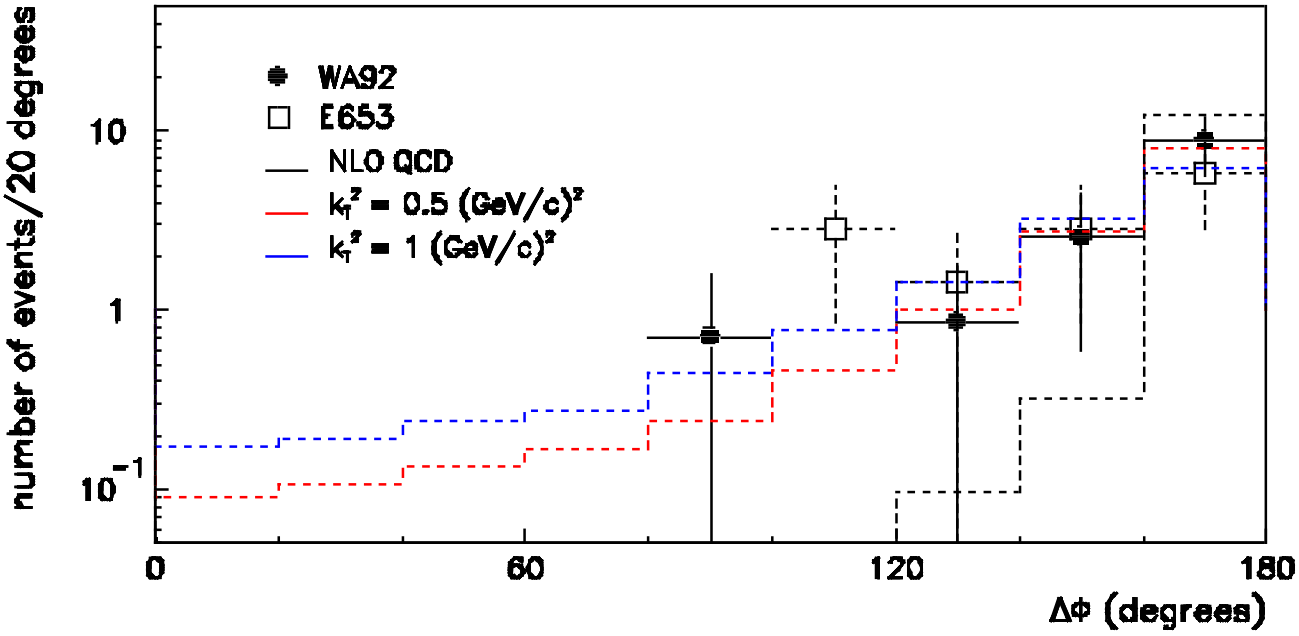
Beauty Pair Selection

- In every event at least one *beauty* decay has been identified
- To identify the associate *beauty* decay stringent cuts are required:
  - **good-quality vertex cuts: minimum distance from the target and from the main vertex, absence of large energy release, not compatibility with photon conversion or K^0 and Λ^0 decays**
  - **minimum transverse distance from the main vertex of 50 μm**
  - **at least one track with $p_{T\,f} > 1$ GeV/*c***
  - **minimum mass wrt the main vertex > 2 GeV/c^2**
- In particular the last two cuts are aimed to avoid misidentification of the *charmed*-hadron daughter as the second *beauty* particle
- Having applied all selection criteria, in 13 events we identify the decay of the second *beauty* particle:
  - **in total we get 39 *beauty* decays**
- The background is negligible for the 13 events with two identified *beauty*-decay vertices
- The composition of our *beauty* sample is well reproduced by simulated *beauty* events

	Experiment	Simulation
B events	26 ± 5.1	26.0 ± 2.4
BB pairs	15 ± 3.9	18.4 ± 2.0
B particles	41 ± 6.4	44.4 ± 3.2
B with D	20 ± 4.5	25.1 ± 2.4
B without D	21 ± 4.6	19.3 ± 2.1
charged B	10 ± 3.2	15.2 ± 1.8
neutral B	16 ± 4.0	14.6 ± 1.8
undetermined B	15 ± 3.9	14.6 ± 1.8
BB pairs after cut on transverse decay length	13 ± 3.6	16.1 ± 1.9
B particles after cut on transverse decay length	39 ± 6.2	42.1 ± 3.1

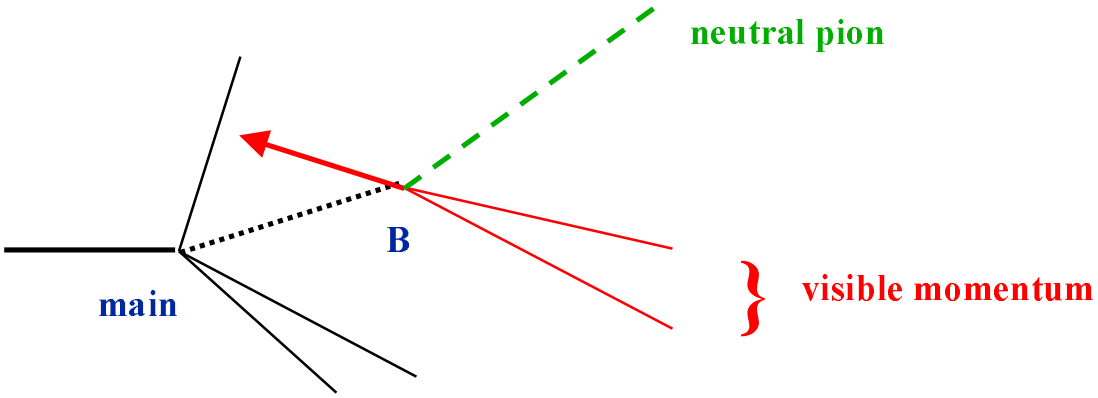
Azimuthal correlation





Momentum Estimate

- To get the x_F and p_T^2 differential distributions, one must know the initial momentum of the *beauty* particle
- As the *beauty* decays are only partially reconstructed, an estimate is necessary
- Usually two methods are used to estimate the momentum of a partially reconstructed decay:
  - **neutral particle method: the decay is kinematically closed assuming one missing pion**

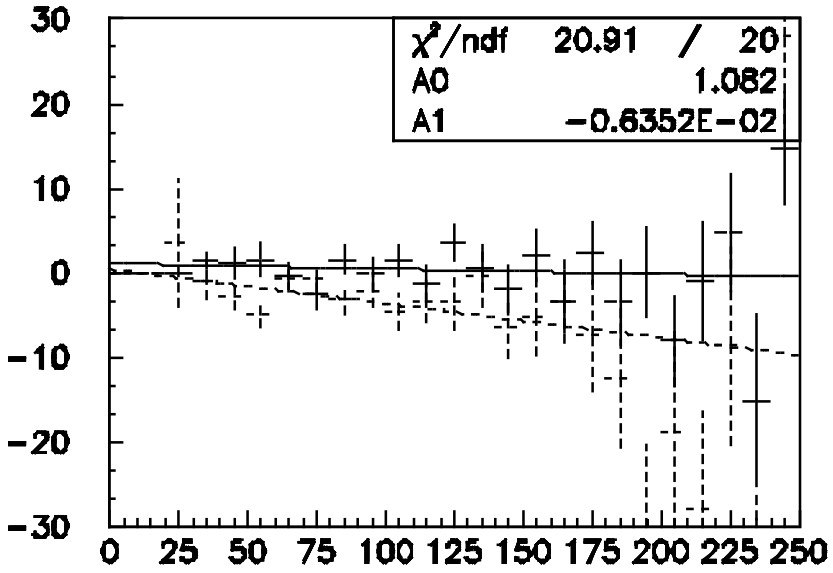


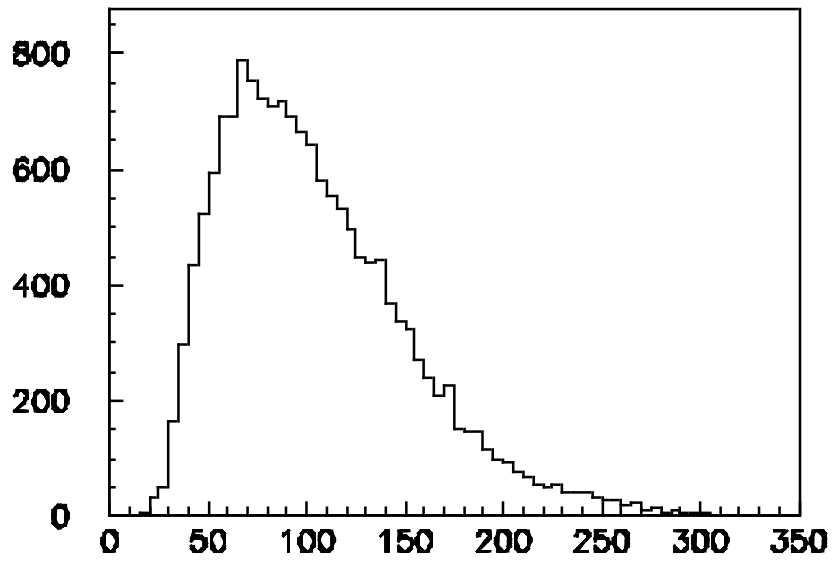
  - **The second method is based on an approximate Lorentz boost:**

$$\gamma = E_{vis}/\sqrt{(M_{vis}^2 + P_{Tvis}^2)}$$

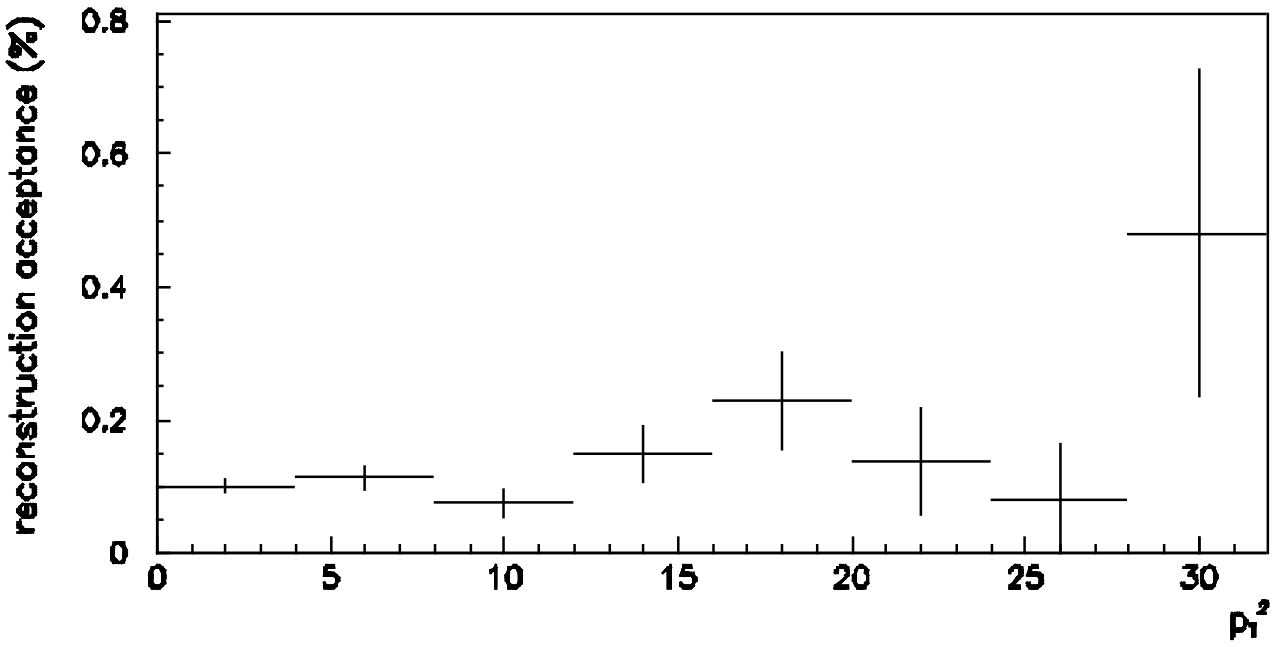
- As none of these methods completely agrees with our MC distributions, we looked for a better estimator, which is a combination of the two previous methods.
- Our momentum estimator of a partially reconstructed decay has been used to measure the kinematical correlations in *charm* events in which one *charm* decay is closed (D -> Knπ) and the other one is only partially reconstructed.

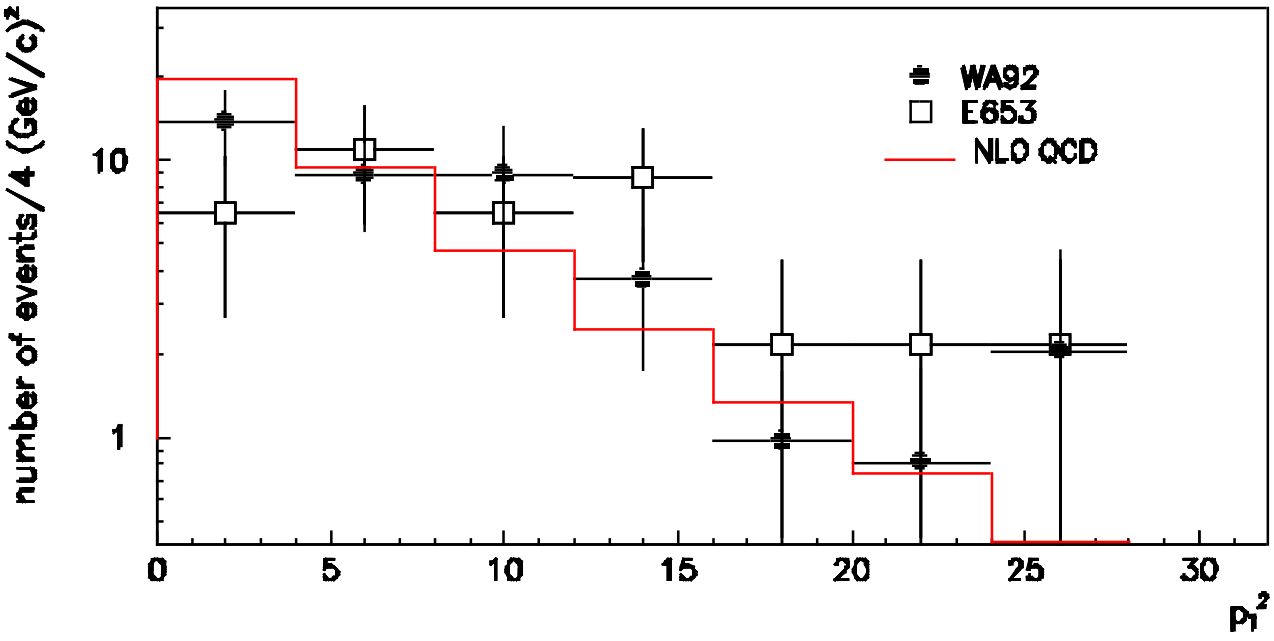
momentum estimator



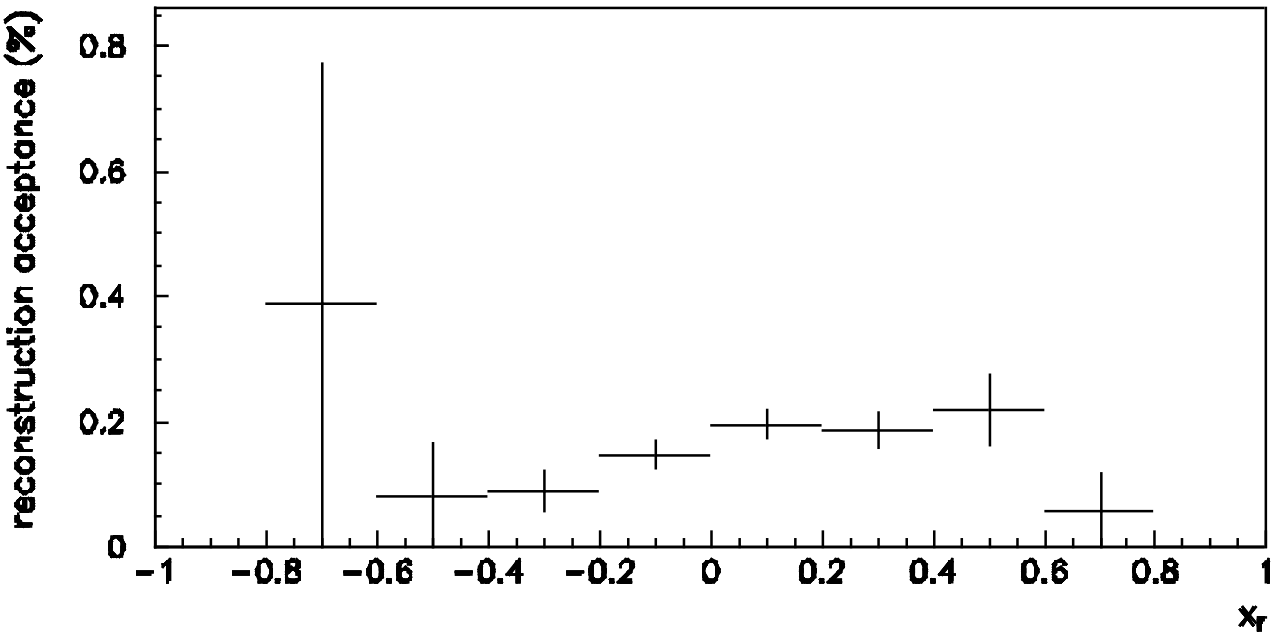


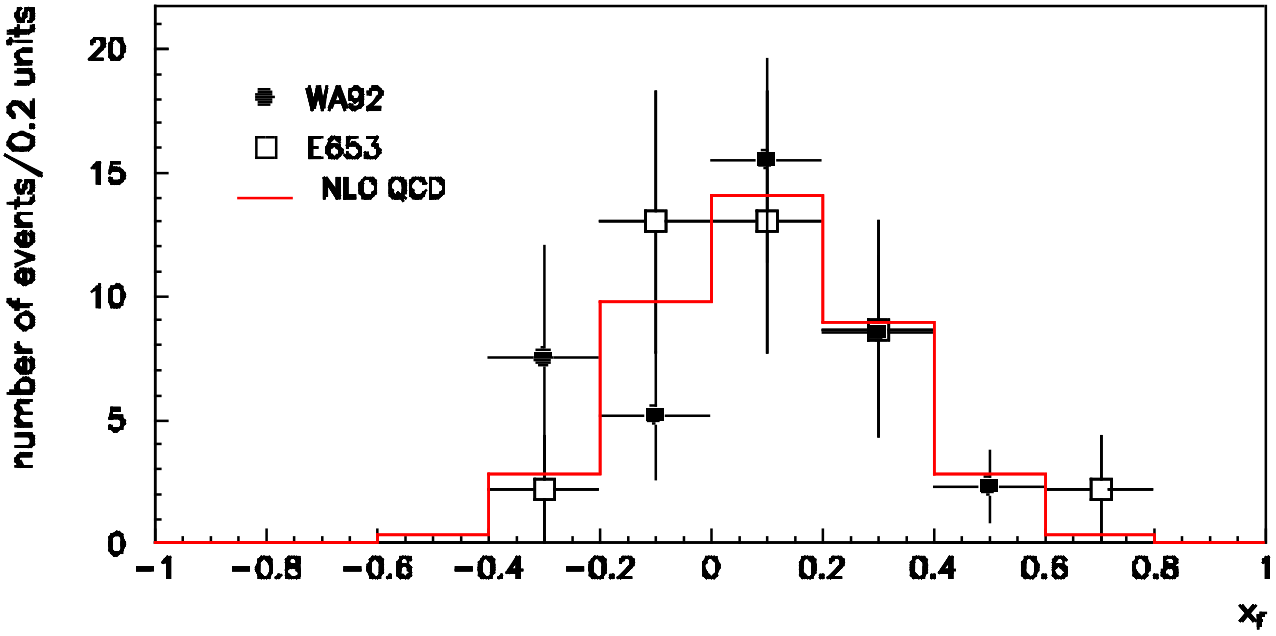
p_T^2(B) distribution



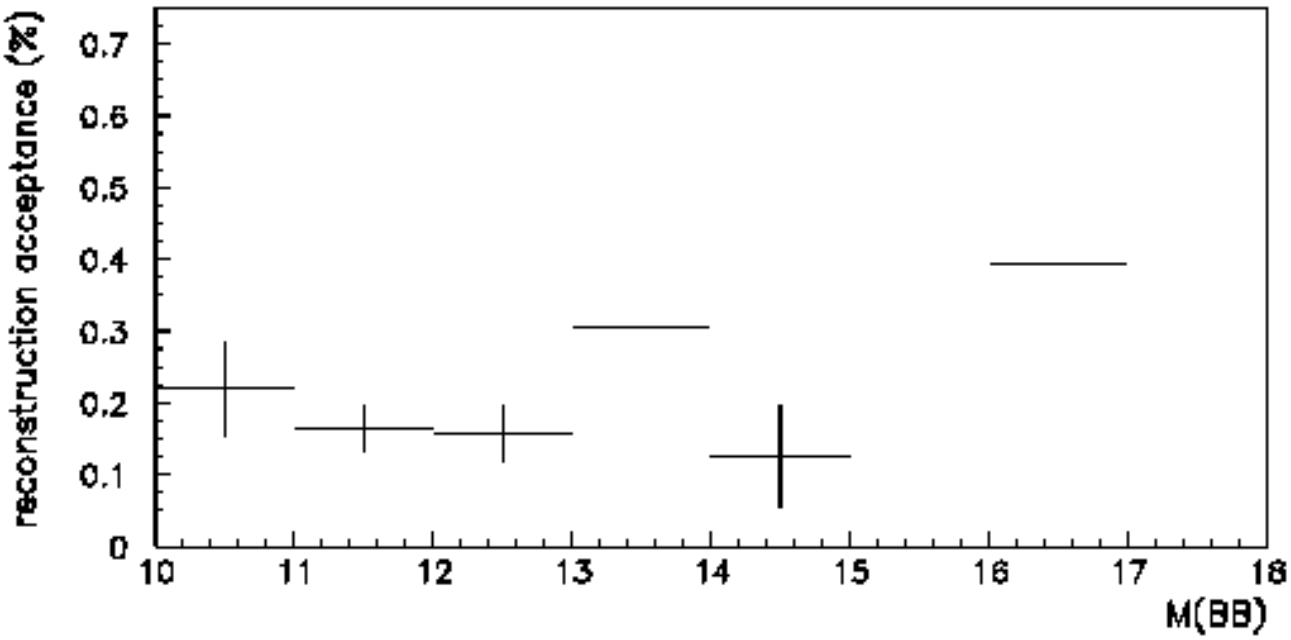


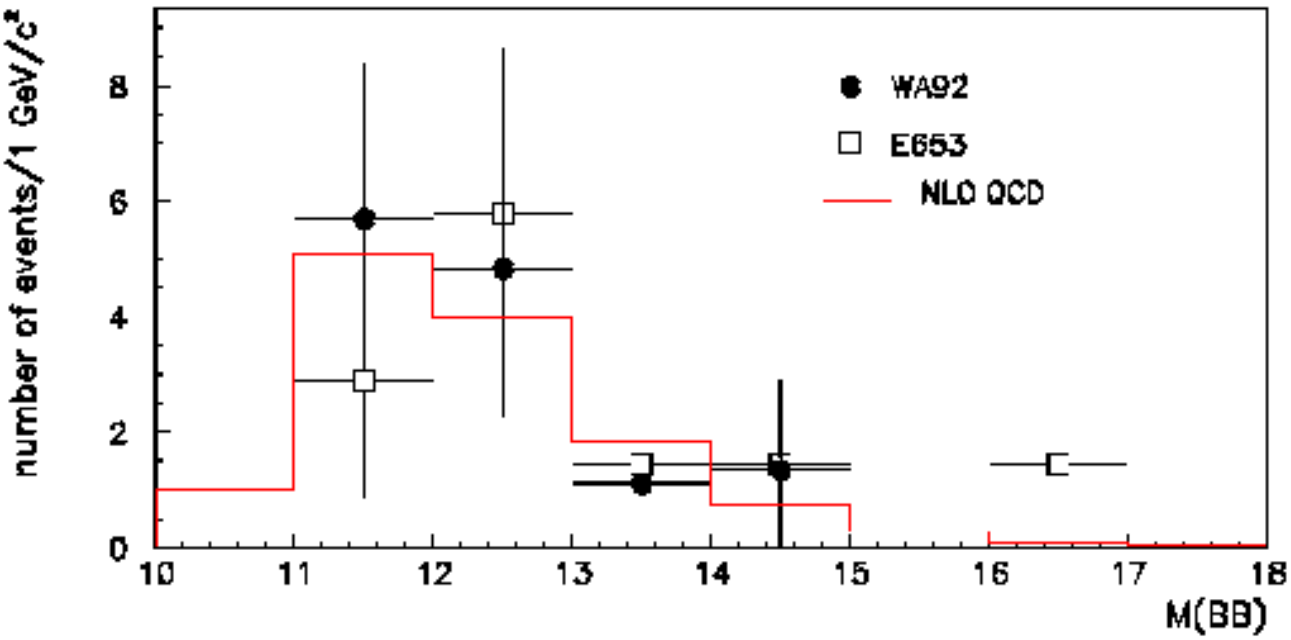
x_F(B) distribution



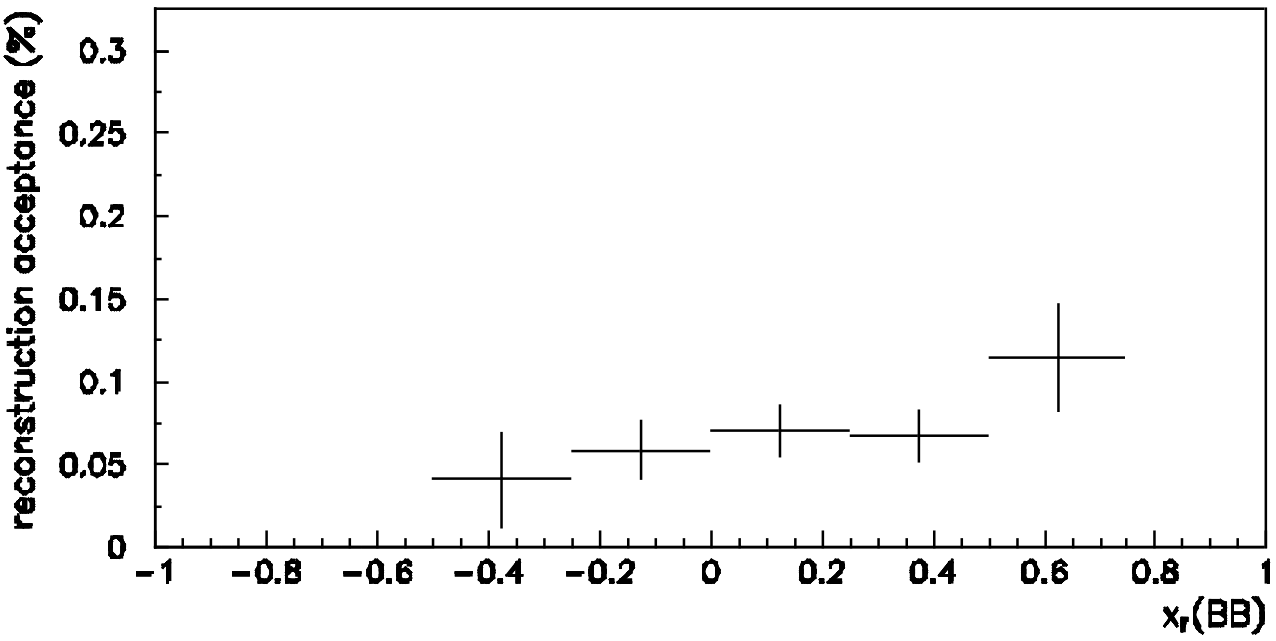


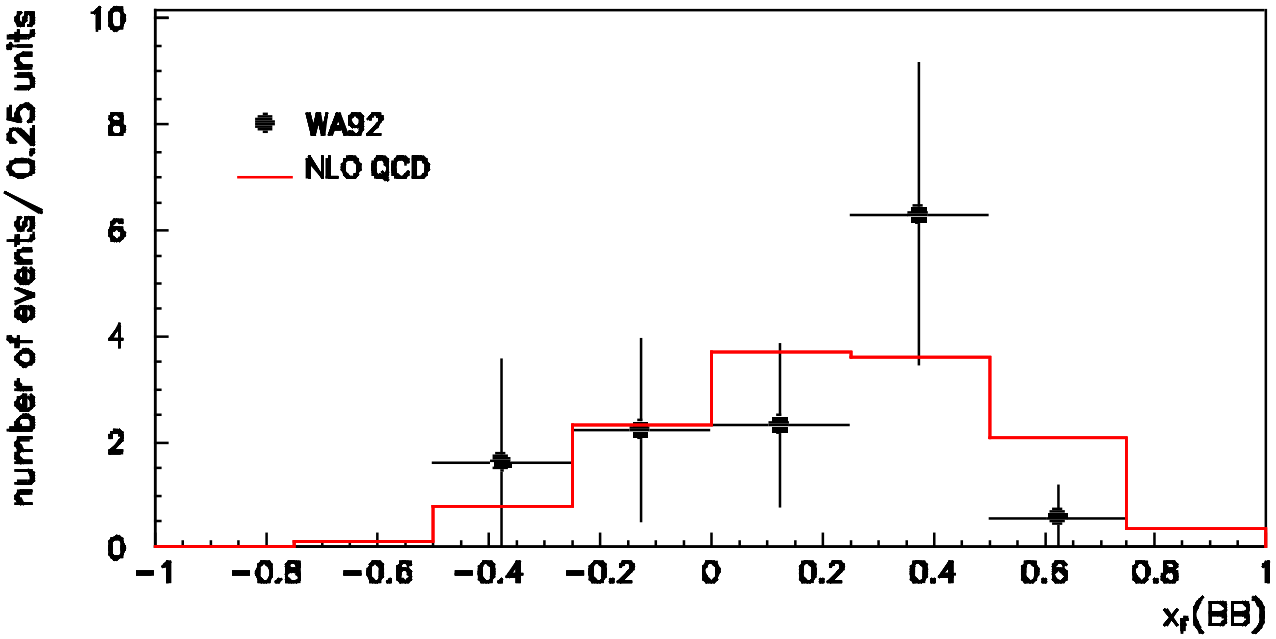
Invariant mass (BB)



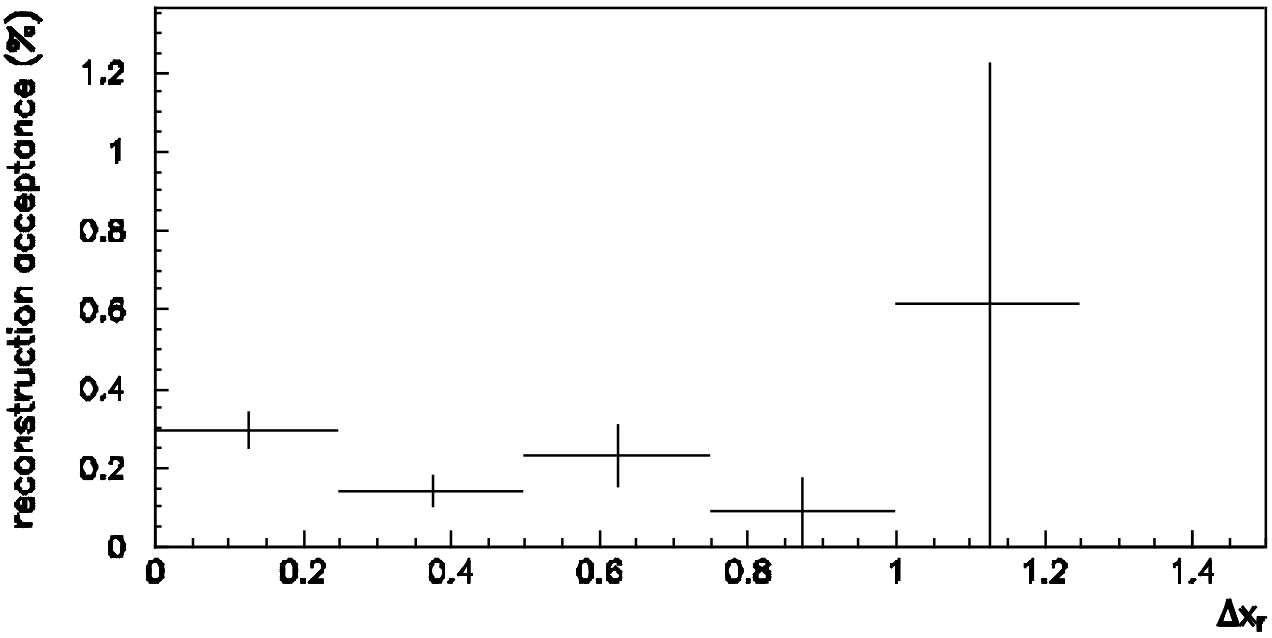


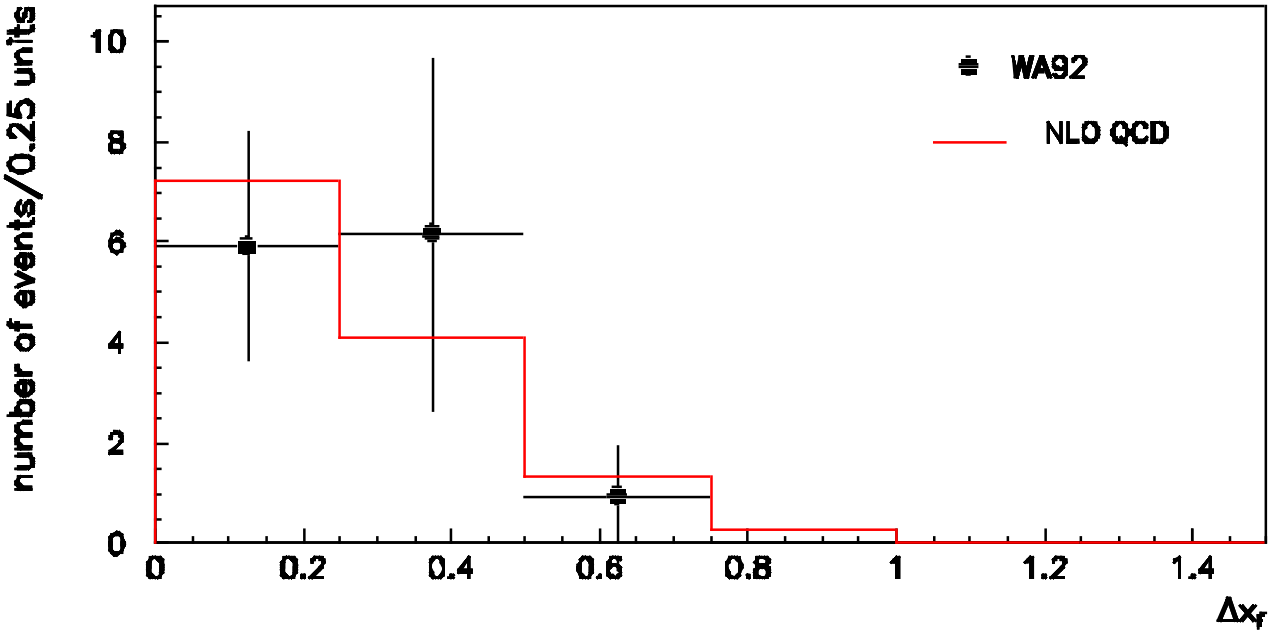
x_F (BB) distribution





$|\Delta x_F|$ distribution





Conclusions

- The WA92 experiment has collected a sample of **26 *beauty* events** with a Copper target: **13 *beauty* pairs** are identified.
- Total *beauty* cross-section has been measured.
- Using a momentum estimator for partially reconstructed decays, also single-differential cross-sections with respect to x_F and p_T^2 and kinematical correlations have been measured.
- The azimuthal correlation between *beauty* particles has been measured (13 pairs); our result is well described by NLO QCD if a $\langle k_T^2 \rangle$ of between 0.5 GeV$^2/c^2$ and 1 GeV$^2/c^2$ is assumed for the interacting partons
- Taking into account the large statistical errors, meaurements agree with the previous distributions of E653 (9 pairs) and with theoretical QCD NLO predictions.